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PRELIMINARY ESTIMATES OF HARBOR PORPOISE ABUNDANCE IN CALIFORNIA FROM 1997 AND 1999 AERIAL SURVEYS

By

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ABSTRACT

Abundance estimates for four stocks of harbor porpoise in California waters based on 1997 and 1999 summer/autumn aerial line-transect surveys are presented. Pooled estimates of abundance (CVs in parentheses) for both survey years by stock are: **Morro Bay**, $N = 932$ (0.41); **Monterey Bay**, $N = 1{,}603$ (0.42); **San Francisco-Russian River**, $N = 6{,}674$ (0.39); and **Northern California-Southern Oregon**, $N = 18{,}493$ (0.37). The abundance for the **Northern California/Southern Oregon** stock includes approximately 5,000 porpoise in southern Oregon estimated from 1997 aerial surveys conducted by Laake et al. (1998). A total of 22,646 (CV = 0.38) porpoise were estimated in California waters, the highest total to date from aerial line-transect surveys in this region.

INTRODUCTION

At the November 2000 meeting of the Pacific Scientific Review Group, National Marine Fisheries Service (NMFS) staff proposed revising stock boundaries of harbor porpoise (*Phocoena phocoena*) along the coasts of California, Oregon, and Washington (National Marine Fisheries Service 2000). Proposed stock boundaries were based on molecular genetic analyses, density minima observed from aerial surveys, and known habitat discontinuities. Chivers *et al*. (2002) provides information on the molecular genetic methods used to discern small-scale population structure of harbor porpoise along the U.S. west coast. Prior to the analyses by Chivers *et al.* (2002), harbor porpoise in California waters were managed as two stocks: (1) *Central California* from Point Conception (34º27N) to the Russian River (38º27N) and (2) *Northern California*, from the Russian River north to the California/Oregon border (42º00N) (Forney 1999; Forney *et al.* 2000). As a result of the molecular genetic studies and an examination of density minima observed from previous aerial surveys, *four* harbor porpoise stocks are now recognized in California, including one trans-boundary stock that extends into Oregon (Carretta *et al.* 2002). The four stocks (from south to north, are: (1) **Morro Bay**; from Point Conception to Point Sur; (2) **Monterey Bay**; from Point Sur to Pigeon Point; (3) **San Francisco-Russian River**, from Pigeon Point to Point Arena and (4) **Northern California-Southern Oregon**, from Point Arena to Cape Blanco, Oregon (Figure 1). This document presents preliminary estimates of abundance for these four stocks from 1997 and 1999 summer/autumn aerial surveys.

METHODS

Aerial line-transect surveys were conducted in California waters from Point Conception north to California/Oregon border out to the 91 m isobath (~50 fathoms) in 1997 and further offshore to approximately the 200 m isobath in 1999 (Figure 1). To ensure that all harbor porpoise habitat was included in the surveys, offshore transects extended to the 200 m isobath or 10 nmi offshore south of latitude 37°N (15 nmi north of this line), whichever was further, in order to include all possible harbor porpoise habitat. Standard line-transect methods were utilized (Buckland *et al.* 1993). Surveys were flown from an altitude of 198 m (650 ft) and an airspeed of 165-175 km/hr (90-95 kts). Two observers searched from bubble windows on either side of a twin-engine Partenavia high-wing aircraft, while a third observer searched from a belly port in the rear of the aircraft. Sightings were verbally reported to a data recorder who entered sighting and environmental information into a laptop computer receiving real-time GPS input. Further details on the survey methodology and aircraft used can be found in Forney (1995, 1999). Raw data were error-checked and formatted using a TRUEBASIC program (*HPASDIST.TRU*) written by the author. Formatted transect data were then imported into the line-transect software program *Distance 3.5* (Thomas et al. 1998), which was used to estimate porpoise density and abundance. Only transect data collected under excellent survey conditions (Beaufort sea state #2, cloud cover #25%) were used in estimating porpoise abundance. The detection function, *f(0)*, was estimated by pooling all sightings from transect segments meeting these environmental criteria. As in previous analyses (Barlow and Forney 1994, Forney 1999), a truncation distance of 300 m was used, which eliminated 34 (5%) of the 680 recorded porpoise sightings. Half-normal, uniform, and hazard-rate detection functions were fit to the perpendicular distance data using cosine, hermite polynomial, and simple polynomial series expansions, and the model fit with the lowest Akaike's Information Criterion (AIC) was selected to estimate density and abundance. Because observers may fail to detect small groups of porpoise at greater distances, mean group size can be biased upwards. For this reason, I employed the size bias regression method in *Distance 3.5* to examine for group size bias. This method regresses the natural logarithm of observed group size against estimated *g(x)* and if the regression is significant at an alpha-level of 0.15, a corrected group size {*E(S)*} is estimated at zero perpendicular distance. If the regression is not significant, then observed mean group size is used as {*E(S)*}. Porpoise abundance was estimated for each geographic stratum using the equation

$$N_i = \frac{A_i \cdot n_i \cdot f(0) \cdot E(S_i)}{2 \cdot L_i \cdot g(0)} \qquad (1)$$

where

A_i = size of study area in stratum *i* (in km^2),

n_i = number of porpoise groups detected in stratum *i,*

f(0) = probability density function (km^{-1}) evaluated at zero perpendicular distance,

$E(S_i)$ = expected group size at zero perpendicular distance,

L_i = length of transect line (in km) surveyed in stratum *i,* *g(0)* = probability of detecting a porpoise group on the transect line.

The probability of detecting a trackline group of porpoise, *g(0)*, was taken from the study of Laake et al. (1997), where *g(0)* = 0.292 with a CV = 0.366. Laake's study used the same aircraft type and observer team methods as our surveys, however survey altitude was 183 m in Laake's *g(0)* study and 198 m for our line-transect surveys.

Separate estimates of porpoise density and abundance were made for 5 geographic strata within California waters: (1) **Morro Bay**, from Point Conception to Point Sur; (2) **Monterey Bay**, from Point Sur north to Pigeon Point; (3) **San Francisco-Russian River**, from Pigeon Point to Point Arena; (4) **Northern California Inshore Waters**, from Point Arena to the California/Oregon border and (5) **Northern California Offshore Waters**. The **Northern California Offshore Waters** stratum was surveyed on a limited basis in 1999 and represents roughly the area between the 90 m and 200 m isobaths from Point Arena to the California/Oregon border. Offshore waters (>90m depths) were surveyed throughout the state, south to Point Conception, but porpoise groups were only detected in northern California, therefore northern California offshore waters were analyzed as a separate geographic stratum. A combined estimate of porpoise abundance for offshore and inshore strata was also calculated and this area is hereafter referred to as **Northern California**. Variance estimates of all density estimates and encounter rates are estimated empirically using the *DISTANCE 3.5* analysis engine. Log-normal 95% confidence intervals of density estimates are calculated using the Satterthwaite procedure, described in Buckland et al. (1993), where

$$\hat{D}_{L95\%} = \hat{D} / C \qquad (2)$$

$$\hat{D}_{U95\%} = \hat{D} \cdot C \qquad (3)$$

and

$$C = \exp\left\{ t_{df\,(0.025)} \cdot \sqrt{\log_e\left(1 + \left[cv(\hat{D})\right]^2\right)} \right\} \qquad (4)$$

Estimates of abundance from southern Oregon based on 1997 aerial surveys (Laake et al. 1998) are combined with estimates from **Northern California** to give a complete estimate for the **Northern California-Southern Oregon** stock. The corrected estimate, N_c (for groups missed on the transect line) for the **Northern California-Southern Oregon** stock is calculated as follows:

$$N_{c(NCalif\_SOregon)} = \frac{1}{g(0)} \cdot \left(N_{u(A)} + N_{u(B)} \right) \qquad (5)$$

where

$N_{u(A)}$ = the *uncorrected* estimate of abundance for **Northern California**,

$N_{u(B)}$ = the *uncorrected* estimate of abundance for **Southern Oregon**,

g(0) = the probability of detecting a group of harbor porpoise on the transect line.

The coefficient of variation (CV) of the combined estimate is

$$CV\ N_c = \sqrt{CV^2 g(0) + CV^2 N_{u(A+B)}} \tag{6}$$

where $$CV^2 N_{u(A+B)} = \left(\frac{\sqrt{\text{var}\ N_{u(A)} + \text{var}\ N_{u(B)}}}{N_{u(A)} + N_{u(B)}} \right)^2$$

It should be noted that *uncorrected* abundance estimates for **Northern California** and **Southern Oregon,** ($N_{u(A)}$ and $N_{u(B)}$, respectively) are uncorrelated, as the parameter *f(0)* was different for each study. 95% confidence intervals for this combined estimate were calculated by generating a log-normal distribution of 5000 values with mean = $N_{c(NCalif\_SOregon)}$ and CV from Equation 6, from which confidence intervals were determined using the percentile method.

RESULTS

A total of 680 porpoise groups were detected during 6,930 km of survey effort in Beafuort sea states of #2 and cloud cover #25%. A uniform key function with 2 adjustment terms provided the best fit to the perpendicular sighting distances (Figure 2). Model fit was good (X^2 = 0.965, df =3, p = 0.81). With the exception of the northern California offshore stratum where there were only two sightings, expected mean group size, *E(S)*, at zero perpendicular distance was used in place of observed mean group size because the slope of the size-bias regression was significant in each stratum. Density and abundance estimates for each geographic stratum are given in Table 1.

DISCUSSION

Abundance estimates for California waters are approximately 23,000 harbor porpoise, the highest total for this species from NMFS surveys dating back to the mid-1980s (Barlow 1988, Barlow and Forney 1994, Forney 1999). Offshore waters deeper than 90 m are included in abundance estimates for the first time and account for approximately 10% (2,300) of the statewide estimate. A permanent set gillnet closure inshore of 60 fathoms (~110 m) in central California was implemented by the California Department of Fish and Game (CDFG) in September of 2002. This closure area extends from Pt. Arguello (34º35N) to Pt. Reyes (38ºN), California. Harbor porpoise habitat in California waters is largely limited to waters <100 m (Barlow 1988; Calambokidis et al. 1990; Carretta et al. 2001) and the current closure effectively eliminates set gillnets from most harbor porpoise habitat. In northern California, set gillnets are prohibited to protect salmon resources in that region. Current stock boundaries reflect genetic and density data, but also correspond to different management concerns in each region, such as the presence or absence of coastal gillnets. These boundaries may change with additional genetic or abundance survey data. The abundance of harbor porpoise in California waters continues to be monitored by NMFS (a 2002 summer/autumn aerial survey was recently completed) and future aerial surveys are planned.

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Table 1. Summary of survey effort, line-transect parameters used to estimate density, and estimates of harbor porpoise density and abundance by geographic stratum. Geographic strata shown in bold represent defined harbor porpoise stocks. The 'Northern CA-Southern OR' stock estimate includes the three subareas listed above it.

1997-99	No. of Groups n	Mean Grp Size s	Expect. Grp Size E(s)	Study Area A	Transect Length L	f(0)	Uncorrected Density D	Uncorrected Abundance N	CV	Lognormal Lower 95% C.I.	Lognormal Upper 95% C.I.	Corrected Density D	**Corrected Abundance N**	**CV**	**Lognormal Lower 95% C.I.**	**Lognormal Upper 95% C.I.**
Morro Bay	81	1.84	1.63	2,154	2,427	4.6505	0.1264	272	0.18	190	389	0.4329	**932**	**0.41**	**430**	**2,022**
Monterey Bay	89	2.28	2.04	1,355	1,222	4.6505	0.3455	468	0.20	316	694	1.1832	**1,603**	**0.42**	**727**	**3,535**
San Francisco-Russian R.	151	2.09	1.91	4,853	1,672	4.6505	0.4016	1,949	0.14	1,486	2,557	1.3752	**6,674**	**0.39**	**3,177**	**14,022**
Northern CA (inshore)	322	1.50	1.43	3,649	1,200	4.6505	0.8911	3,251	0.11	2,608	4,054	3.0516	11,135	0.38	5,375	23,067
Northern CA (offshore)	2	2.00	-	7,375	102	4.6505	0.0911	672	0.61	193	2,337	0.3120	2,301	0.71	556	9,529
Northern CA (all)	324	1.50	-	11,024	1,302	4.6505	0.3558	3,923	0.14	2,938	5,239	1.2188	13,436	0.39	6,228	28,985
Southern Oregon Area VI	37	2.38	2.38	2,246	396	5.63	0.6251	1,404	0.32	-	-	2.1407	4,808	0.49	-	-
Southern Oregon Area VIF	1	1.00	1.00	1,671	64	5.63	0.0437	73	1.03	-	-	0.1496	250	1.09	-	-
Northern CA-Southern OR	-	-	-	-	-	-	-	-	-	-	-	-	**18,493**	**0.37**	**8,358**	**35,565**

Southern Oregon data from Laake et al. (1998)

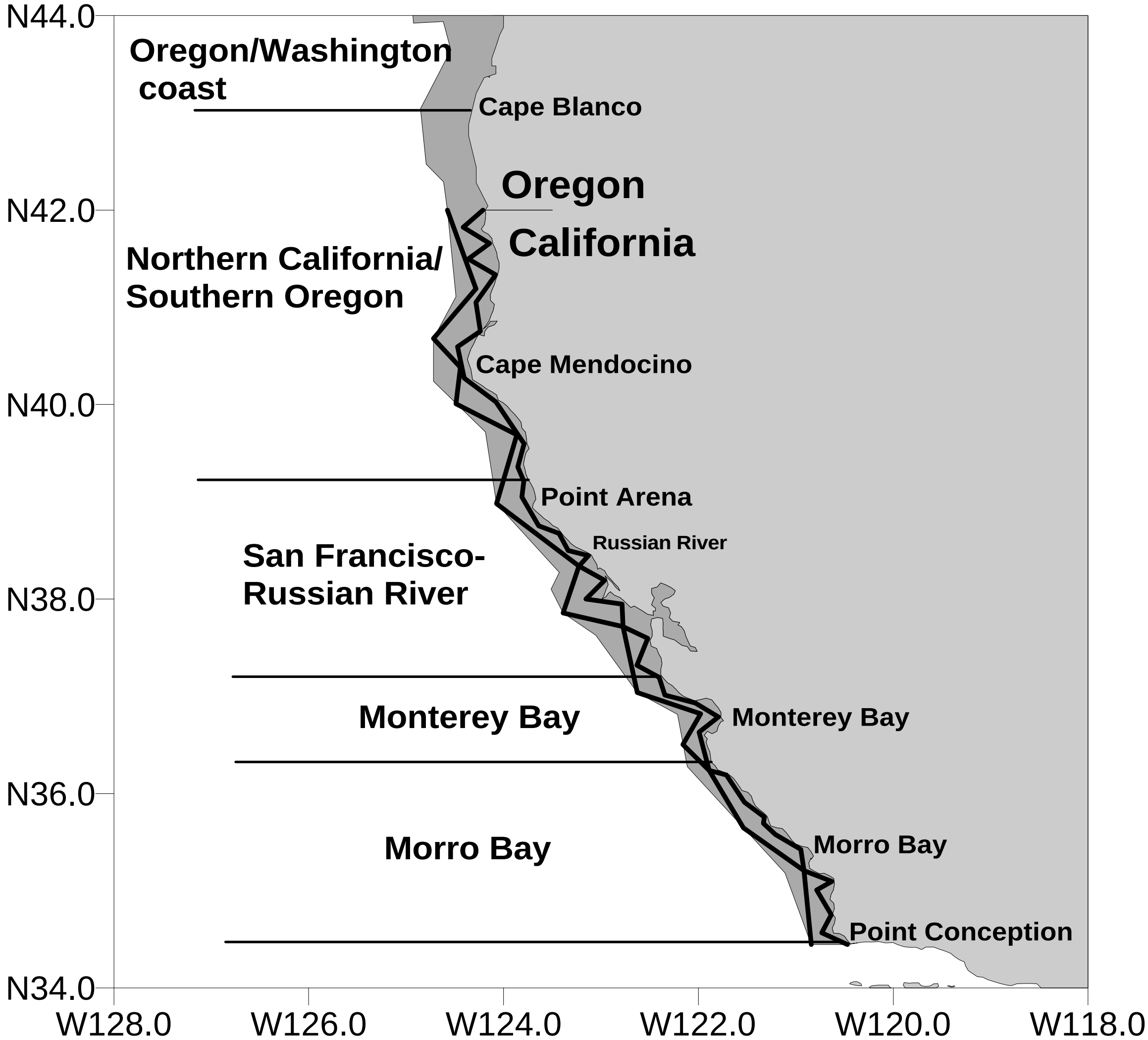

Figure 1. Aerial survey study area, showing harbor porpoise stock names and boundaries, transect lines (bold), and approximate range of harbor porpoise from shore to 200 m in this region (shaded).

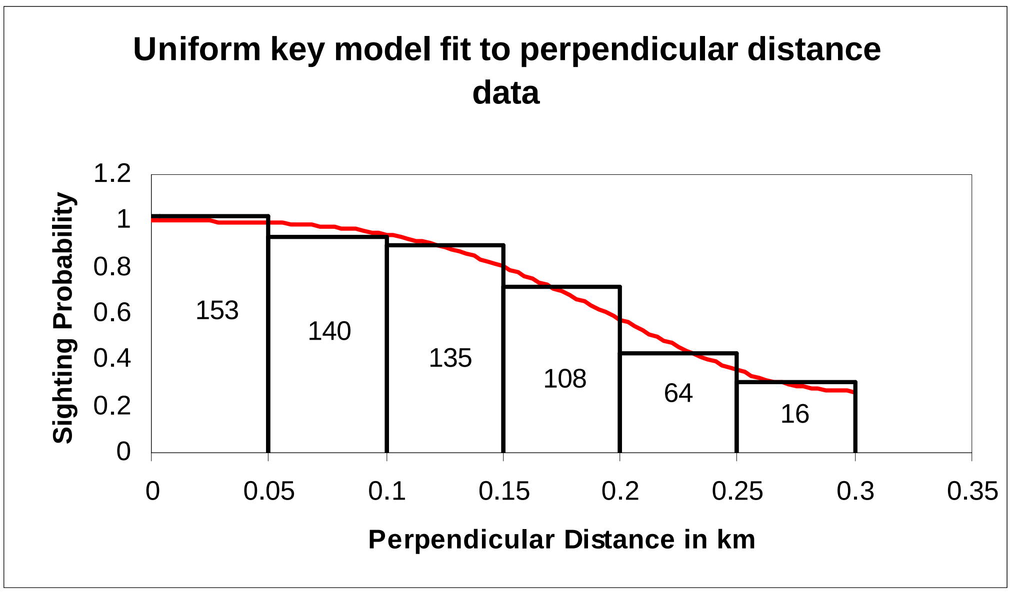

Figure 2. Probability density function fit to perpendicular sighting distances for Beaufort sea states 0-2 and cloud cover $\leq$ 25%. The uniform model fit with 2 cosine adjustment terms is shown (*f(0)* = 4.6505 km^{-1}; c^2 = 0.965, df = 3, p = 0.81). Sample sizes for each distance bin are also shown.